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An Elastic Hybrid Sensing Platform: Architecture and Research Challenges

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Abstract

The dynamic provisioning of hybrid sensing services that integrates both WSN and MPS is a promising, yet challenging concept. It does not only widen the spatial sensing coverage, but it also enables different types of sensing nodes to collaboratively perform sensing tasks and complement each other. Furthermore, it allows for the provisioning of a new category of services that was not possible to implement in pure WSN or MPS networks. Offering a hybrid sensing platform as a service results in several benefits including, but no limited to, efficient sharing and dynamic management of sensing nodes, diversification and reuse of sensing services, as well as combination of many sensing paradigms to enable data to be collected from different sources. However, many challenges need to be resolved before such architecture can be feasible. Currently, the deployment of sensing applications and services is a costly and complex process, which also lacks automation. This paper motivates the need for hybrid sensing, sketches an early architecture, and identifies the research issues with few hints on how to solve them. We argue that a sensing platform that reuses the virtualization and cloud computing concepts will help in addressing many of these challenges, and overcome the limitations of today's deployment practices.

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1. Introduction

Wireless sensor networks (WSNs) have been widely used for implementing large and small scale sensing infrastructures, as means to collect data about our surroundings physical world in many application areas (such as health, environmental monitoring, agriculture, etc.). With the help of sink and gateway nodes, sensor nodes in WSNs collaborate together to perform well defined sensing tasks, process, and communicate the collected data. The sink, or a base station, is a WSN node that allows the communication between sensor nodes and the outside world. It collects data from sensor nodes, on which it performs simple processing before it forwards it to the interested devices. WSNs have been initially designed to be used for a specific domain and perform a single task and cannot be easily reused

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to run new applications. This results in costly and redundant deployments. On the other hand, mobile phone sensing (MPS) is an emerging people-centric paradigm that incorporates the concept of “human-as-a-sensor” [7]. Recent mobile phones that are equipped with built-in sensors and carried by people (crowd) are used to collect data about their surrounding environment [8].

Although WSNs' deployments have been successfully used to collect real-time information, the static nature of the WSN nodes limits the capabilities of the sensing applications as additional deployment of sensor nodes is required for more spatial coverage. Integrating WSNs and MPS does not only results in a highly flexible and large-scale collaborative computing-enabled sensing infrastructure and benefits from the advanced sensing capabilities of mobile phones, but also from the mobility of nodes that results in extended spatial coverage where traditional static sensors are difficult to deploy. Moreover, MPS brings several advantages to sensing applications. First, the human factor in MPS, also known as participatory sensing, has additional benefits since the users can directly enhance the sensing service functionality by controlling the service or by providing manual information input (that is, human sensing). For example, by typing text (e.g, personal opinion, current sensation), taking images, recording audio/video. Second, the large number of mobile phones owned and operated by people and that have an increasing processing power can be used to perform the same sensing tasks as a WSN, without requiring the acquisition of new sensing hardware nor significant deployment effort and cost. MPS can also take advantage of the participatory sensing paradigm which adds a social aspect (community sensing) to the sensing process.

The work presented in this paper focuses on how to provide an elastic framework for hybrid sensing service provisioning. A hybrid service is a service that relies on both mobile phones and WSN infrastructures to collect data and achieve the sensing service goal. Service provisioning covers the whole life cycle of a service, which includes development, deployment and management of services. The framework elasticity refers to the ability to adapt the resources to the service's need. In other words, resources are allocated dynamically in order to satisfy the quality requirements of the sensing service. The aim is to integrate WSN and MPS paradigms in order to create a collaborative sensing environment where different kind of sensor nodes (static and mobile) can be used as source of information and to use the available nodes in an efficient way (i.e. the same set of nodes can be used to provision different sensing services). Such integration enables collected data from WSNs to be complemented with MPS data. Virtualization is a promising enabler for resource efficiency and platform elasticity. It allows physical computing resources to be divided (sliced) into several isolated logical (virtual) units so that they can be efficiently shared and used by multiple independent users/applications [9,6]. A Lot of work was done in the context of both WSN and MPS service provisioning. However, only few attempts were carried out regarding hybrid sensing. In this paper, we present a scenario that illustrates our vision for a hybrid sensing platform, and which also pinpoints the motivations behind. We also propose an early architecture for the platform and identify the related research challenges.

The remainder of this paper is organized as follows: in Section 2 we discuss a motivating scenario along with the derived requirements. Section 3 presents the related work. In Section 4 and 5 we describe the proposed overall framework architecture and detail the associated challenges. In Section 6 we conclude the paper and present some future research directions.

2. Motivation and Requirements

2.1. Motivating Scenario

In this scenario, a set of heterogeneous sensor nodes are used to provide two services: tracking of electrical vehicle charging stations, and charging stations' deployment planning.

Service 1: Electric Vehicle Charging Stations Tracking System Electric vehicles (EVs) are environment friendly, they are considered as an alternative to fuel-based cars, and they are being sold at an increasing rate in North America. However, harsh weather conditions during the winter, especially in Canada and the cold parts of the United States, have an impact on the life span of the car's battery. This makes the battery charge unpredictable and leaves the owners of EVs in doubt: How long will the battery last? Will it allow the driver to reach his final destination?

To help and assist EVs' owners while traveling, there is a need for a system that efficiently tracks the locations of EV charging stations (CSs) and assist owners with relevant and real-time information about weather, road, traffic conditions, and waiting time in the EV stations. In this first part of the scenario which is depicted in Figure 1, we consider an EV owner, John, who is planning to go on a long road trip for which he needs assistance. Using an application installed on his mobile phone, John can configure his trip and then get the locations and characteristics of